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A SIXTEENTH-CENTURY PLANETARIUM

By Frederick A. Stebbins
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It would be difficult to find a more fascinating insight into medieval astronomy than that afforded by a glimpse into that wonderful old book entitled *Astronomicum Caesareum* by Peter Apian, with its elaborate coloured diagrams with movable parts. It was my good fortune to spend an hour handling a copy of that magnificent volume in the rare book vault of the New York Public Library, and a photostat of two pages permitted further study of a selected portion. Here is a work where the scientist, the historian, the artist, the bibliophile, and the just plain curious can all drink deeply and go away refreshed.

Apian was born in Saxony, and his dates are 1495–1552. The book was published at Ingolstadt in Bavaria in 1540. The "Caesar" in the title was no Roman, but Emperor Charles V, to whom the book was dedicated. Apian was an astronomer interested in simplifying mathematics, so he filled his book with diagrams with movable parts attached to the pages to make it easy to calculate the positions of the planets among the stars. Figure 1 shows a page containing the instrument for calculating the longitude of the planet Jupiter. In the original the octagon is 11½ inches across. The ecliptic circle is printed on the page and attached to it are three large and two small disks of heavy paper that turn on three different centres. The whole has been painted by hand, over the printing, in a number of colours. Another page has a simpler instrument, but equally large, for calculating Jupiter's latitude.

To get an idea of the scope of the book, there is a roughly similar pair of instruments for each planet, and others for the sun and moon. Those for the moon are particularly complicated since Apian was interested in predicting eclipses. The text is in Latin and tells how to operate the

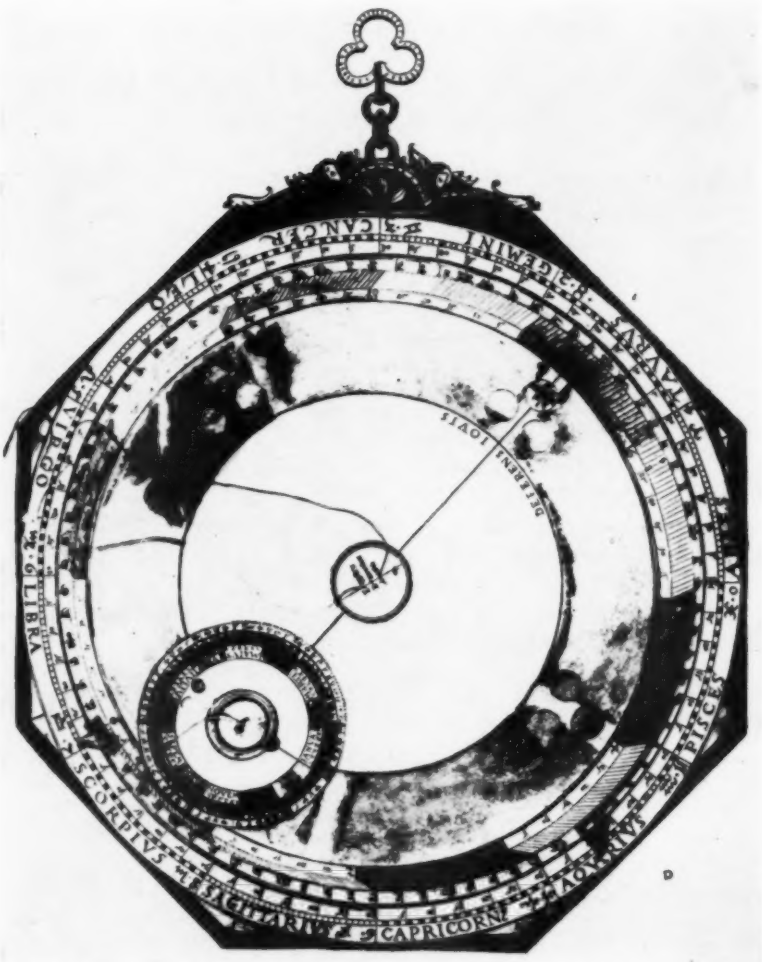

FIG. 1—Peter Apian's instrument for calculating the longitude of the planet Jupiter. (From the original in the Maitland Collection, The New York Public Library.)

instruments. There is a chapter on comets, and Apian is credited with the discovery that a comet's tail always points away from the sun. The book is profusely ornamented in a rather florid style, so that the effect is rich and sumptuous in the extreme. It was issued just three years before Copernicus's great work on the motion of the earth, and therefore we find Apian loyally following the old Ptolemaic astronomy with the fixed and immobile earth, the system so beautifully used as the background to Dante's *Paradiso*. It would seem at first glance that these paper instruments, all based on an erroneous inside-out system of astronomy, could not give results anywhere near the truth. Surprisingly enough, they still work quite well.

To give a brief review of Ptolemaic astronomy (with emphasis on Jupiter), the ancients assumed that the fixed stars were attached to the surface of an enormous sphere with the earth at the centre. Within the sphere of the stars was another sphere, also enormous, nearly concentric, transparent, and invisible, the deferent of Jupiter. The sphere of the stars turned around in twenty-four sidereal hours, and carried the deferent around with it, but the deferent had a very slow eastward rotation of its own that would carry Jupiter against the background of the stars so as to travel completely through the zodiac in about twelve years. To explain Jupiter's annual retrograde motion, it was supposed that the planet was not attached directly to the deferent, but rode on the surface of a much smaller sphere, the epicycle. The centre of the epicycle was carried on the surface of the deferent. As the deferent turned slowly, the epicycle turned rapidly in the same direction, thereby producing the forward and back motion characteristic of the planets. Ptolemaic astronomy insisted that all motion must be in circles. To explain irregularities that we now know are due to the ellipticity of Jupiter's orbit, the centre of the deferent was placed a short distance from the earth. To explain Jupiter's changes of velocity, later formulated in Kepler's second law, it was supposed that the deferent rotated so that the centre of the epicycle swept over equal angles (not areas) in equal times as seen from an equant point, still farther from the earth. In figure 2 the letters *A*, *D*, and *E*, seen in the upper right corner, are respectively the centre of the earth, centre of the deferent, and the equant, all lying on the so-called line of centres. As the early astronomers supposed that the earth was fixed in space, they had no need to account for its annual motion, or its minor irregularities. Strangely enough, they blundered into doing both. The epicycle was a reflection of the earth's annual motion. Also they did not locate the line of centres quite where we would put the line of apsides. Professor D. J. Price of Christ's College, Cambridge, has shown

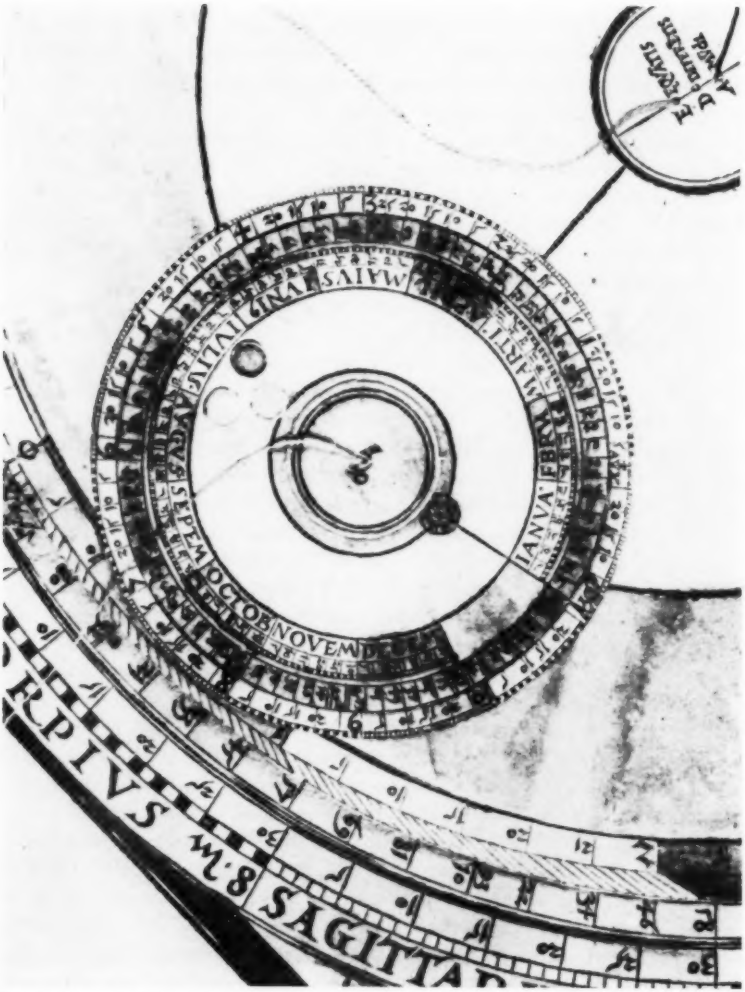

FIG. 2—A part of figure 1, shown approximately the same size as the original. (From the original in the Maitland Collection, The New York Public Library.)

that this divergence in some measure caused the eccentric deferent of Jupiter to do double duty, and account for minor irregularities, not only of Jupiter, but also of the earth as well. To close this brief summary of Ptolemaic astronomy, outside the deferent of Jupiter was a similar system for Saturn, while inside it were nested systems for Mars, the sun, Venus, Mercury, and the moon in that order.

Apian's curious instruments provide paper models of the deferent and epicycle, plus a number of other disks to aid in setting them. These devices are known as volvelles, or more particularly equatoria. Such instruments are not uncommon, but Apian's are unusual in that most of the information is printed on the disks themselves, and few supplementary tables are needed. He gives two brief ones. The first furnishes the longitude of Jupiter at the beginning of each century, calculated according to a uniform motion that averages out all the irregularities. With true Teutonic thoroughness his tables run from 7000 B.C. to A.D. 7000. The volvelle is set as follows. The largest rotating disk is centred on *A*, the centre of the earth and centre of the ecliptic circle. As the first step (1) the dark projecting index (seen in figure 1 near the "R" in "Aquarius") on the edge of the first disk is turned to the degree of the ecliptic for the proper century as found in the table. For December 31, 1900, the position is 28° 40′ in Sagittarius. To find the year in the century, the rim of the disk, beginning at the index, is divided at intervals of 30° 21′ 43.8″, one division being marked for each year. The divisions go around and around counterclockwise, never quite coinciding, until there are one hundred of them. The second step (2) is to advance the index to the point just indicated on the ecliptic by the division for the last completed year of the century. That is, for a current prediction we would push the index to the place where the division for 58 was at the first setting. The division next to the index is subdivided every ten days, and for step (3) we set the index as nearly as possible for the day in the year. We now have Jupiter's position by uniform motion on the date desired. The second rotating disk is also centred on *A*. For step (4) we turn it so that the line of centres from *A* to *E* points to 23° 22′ in Virgo. The outer part of the second disk is covered by straight lines that look like ornamental shading. They have a more serious purpose. For step (5) we take the line that comes nearest to the first index and use it to cross over to the circle printed on the second disk. That circle is centred on *D*, and the line we have followed strikes the circumference at a locus that would be reached by a point moving with the same average motion as Jupiter, but actually moving so as to sweep over equal angles in equal times as seen from *E*, the equant point. This enables us to line up the epicycle. The

second rotating disk carries on its surface at *D* the pivot for the third disk, the deferent, and the three letters *A*, *D*, and *E*, are on a flange attached to the upper end of the pivot. Our next step (6) is to draw a thread from *E* across the locus found by step (5) and then turn the deferent, on centre *D*, so as to put the centre of the epicycle under the thread. The epicycle, riding on the deferent, is made of two small concentric disks. The larger has an ecliptic, and 0° of Aries also goes under the thread just mentioned on the side away from centre *D*. Apian's second table gives a setting for each century, and by steps (7), (8) and (9) the second circle of the epicycle is set in a manner analagous to steps (1), (2), and (3). The last step (10) is to draw a thread from centre *A* across Jupiter itself (seen on the line from the centre of the epicycle to January 1), and where the thread cuts the ecliptic is the longitude of the planet. Another instrument gives the latitude, but Ptolemaic astronomers were less successful with latitudes as they ran the lines of nodes through the earth.

How well does it work? A paper volvelle was made from the photostat of Apian's book and certain longitudes were calculated with it. His tables were used, and all his other values. The only concession to modernity lay in dropping thirteen days to allow for the change from the Julian to the Gregorian calendar. In the table below are listed Jupiter's longitudes measured on the ecliptic for the first day of each month in 1959, the points being calculated from the right ascensions and declinations in the *American Ephemeris and Nautical Almanac*. In the next column are the values obtained by setting Apian's volvelle to dates thirteen days before. The table carries Jupiter through a complete cycle of retrograding.

Date 1959	Almanac	Apian
	° ′	°
January 1	233 58	232½
February 1	238 54	237
March 1	241 41	239½
April 1	241 57	239½
May 1	239 18	238
June 1	235 28	233½
July 1	232 41	230½
August 1	232 19	230½
September 1	234 44	233½
October 1	239 10	237
November 1	244 14	242
December 1	251 49	250½
January 1, '60	258 44	257

The average error is 1°51′, not consistent with twentieth century precision. However, consider Apian's handicaps. His system of astronomy was wrong, both in general concept and in detail. His observations, and those of his predecessors, were all made without telescopic sights and without clocks worthy of the name. Four hundred years have elapsed for errors to accumulate. Lastly, paper disks never lie quite flat and have play at the centre. It would seem that we in the age of the atom must concede that a very creditable piece of work was done. Let us take off our hats to Peter Apian.

PHOTOELECTRIC SPECTROSCOPY

By D. M. Hunten
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Quantitative measurements of spectra are normally made with the aid of photographic emulsions; until recently this has been the only important method. A similar situation existed in the measurement of stellar magnitude; but now many of the most useful observations are made with a photomultiplier. The important advantage is that this device is highly linear in its calibration and also that it is not destroyed in each measurement; it can be used over and over with the same calibration. It is natural that attempts should be made to use the same technique for spectroscopy, because the advantages should still hold. The writer is not competent to discuss the astronomical applications, but many of the same considerations are important in auroral spectroscopy with which he has considerable experience. A spectroscope with electrical detection is called a spectrometer; a typical one is shown in figure 1. Instead of the photographic plate there is an exit slit and behind it a suitable detector which thus is exposed to only one wave-length (or really, a band of wavelengths) at a time. A scanning mechanism moves the spectrum past the slit and the intensities are recorded on a chart as in figure 3. Sometimes the slit and detector are moved instead, but usually this is less convenient. There is nothing new about spectrometers; they have always been necessary in the infrared where photographic plates are not sensitive, and such detectors as thermocouples and bolometers were and still are used. What is new is that it is now possible to build a spectrometer which is sensitive enough to be used with faint emissions such as aurora, airglow, and twilight, and presumably stars and nebulae too. As with stellar photometry, this is possible because of the availability of photomultipliers

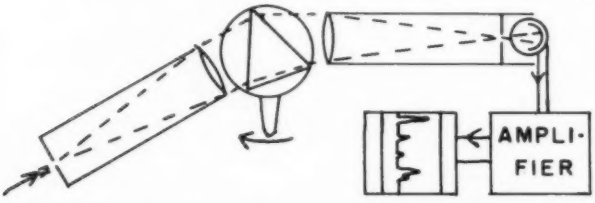

Fig. 1—A prism spectrometer, scanned by rotating the prism.

which make the tiny photoelectric current larger by factors of over a million and thus make it easy to measure. They cover essentially the same part of the spectrum as photographic emulsion, with a long wavelength limit of about 10,000 A. for faint light. Though an emulsion is available with response to 13,000 A., it is not sensitive enough for auroral spectroscopy, and the effective limit is 9000 A. With bright aurora excellent spectra have been obtained in 10 seconds; photographic methods require perhaps 15 minutes. On the other hand, faint aurora cannot be measured at all with a spectrometer at present, while the spectrograph

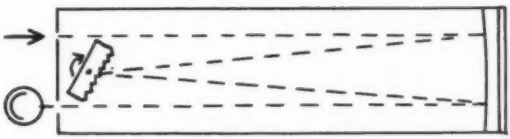

FIG. 2—A grating spectrometer of the Ebert-Fastie type.

can be exposed for hours to give a useful plate. For astronomical work another consideration may be important: photoelectric measurements can be made on only one object at a time, while a whole field can be photographed in one exposure. The accuracy and convenience must be balanced against the inefficiency.

The photomultiplier is not the only new detector which has been applied; photoconductive cells such as lead sulphide give useful sensitivity further into the infrared and have been applied to the aurora and airglow by A. Vallance Jones and his collaborators at Saskatoon. In this region there is no competition from photographic plates.

Let us now compare spectrograph and spectrometer point by point for the purpose of auroral spectroscopy. The spectrometer has a highly linear and reproducible response; the spectrograph has a non-linear response which is different for each plate, so that each must have its individual calibration; and at best the accuracy of this is 5 per cent. The spectrograph can detect much fainter light by means of a long exposure, but if the light is bright enough, the spectrometer can get a spectrum in much shorter time; 10 seconds is typical. For the highest sensitivity the scan of the spectrometer must be restricted to a few hundred Angstroms or even less; the spectrograph always covers a range of 1000 to 5000 A. If the intensity of the source changes during the scan, the spectrometer will give false relative intensities across the spectrum, unless special steps are taken; the spectrograph has no such fault since the whole plate is being exposed all the time. However, the spectrometer's results may be cor-

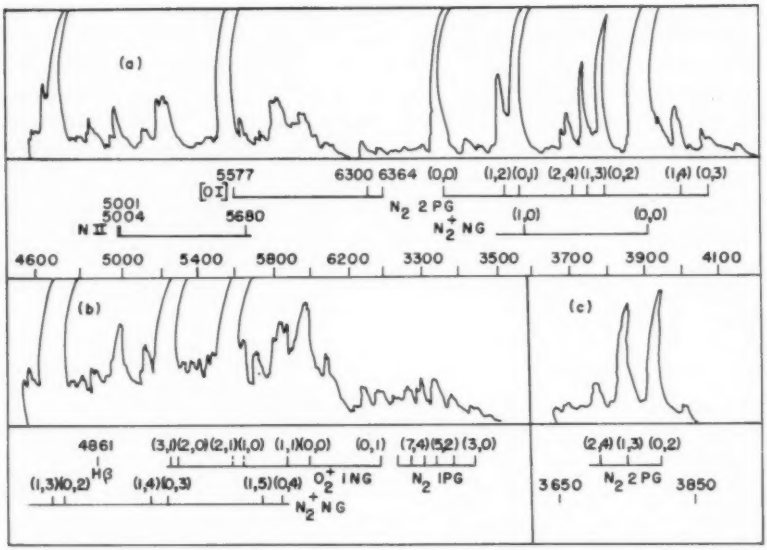

FIG. 3—Representative spectra of aurora, each taken in 10 seconds. In (a) the first-order blue, green, and red are followed by the second-order ultraviolet; in (*b*) the latter is cut out by a yellow filter. (c) expands a small region for detailed study.

rected if the source intensity is also recorded by another photomultiplier; or better yet, the correction may be made automatically by recording the ratio. It should be remembered that astronomers are not exempt from this difficulty since the intensity of a star or the sun is affected by the seeing.

It should be possible to improve the sensitivity of the spectrometer by making a very slow scan lasting an hour or even longer, but one hesitates to do this especially with a fluctuating source like the aurora. But the same result may be had by taking a large number of short spectra one after the other for the same total time, and adding them all together. This can be done with the individual tracings, but it is much easier to do it electrically as the spectra come in. We call the device which does this a "memory unit" and have used it with considerable success on various radiations in the twilight. It is possible that further use of this technique may make the photoelectric method just as good as the photographic even for very faint sources.

All available photomultipliers have the defect of an appreciable dark current; that is, the cathode emits a few electrons even when no light

falls on it. It appears that this emission is essentially thermionic in nature, just as in a radio tube, and it can be greatly reduced by cooling the tube. The most common cooling agent is dry ice, but for the best tubes a simple mechanical refrigeration unit is good enough and much more convenient; the compressor is of the kind used in ordinary refrigerators. The cooling reduces the dark current from several thousand electrons per second to one or two per second; the amplification within the tube is great enough so that even such small currents can be easily observed. One might wonder why the dark current should be annoying as long as it stays constant; but when signal current may be only ten electrons per second it can be lost completely in a dark current of 1000 per second.

The optical design of the spectrometer is different in some respects from that of the spectrograph. Of course, they must both include a slit, a collimator, a grating or prism, and a camera or the equivalent; and the spectrometer needs a scanning mechanism and an exit slit. But the design of the camera and the dispersing system must satisfy entirely different requirements. To get a fast spectrograph one needs most of all a fast camera, and often the Schmidt is used; many auroral spectrographs use Schmidts of relative aperture f/0.8. The speed is approximately inversely proportional to the dispersion, so that prism instruments are usually faster than grating types even when the modern efficient gratings are used. In a spectrometer the speed of the "camera" is irrelevant as long as all the radiation from a line can get through the exit slit and can be focused on to the cathode. And the sensitivity increases with the dispersion, because a high dispersion allows the slits to be opened wider for the same resolution. The grating therefore has a clear superiority over the prism; this is reinforced by the fact that gratings are available in larger sizes than prisms, since a large instrument passes more light than a small one. Reflection gratings have the further advantage that the spectrum is easily scanned by rotating the grating. It is then convenient to use concave mirrors for collimation and focusing since they are perfectly achromatic. In many designs two separate paraboloids have been used, but for most purposes the Ebert-Fastie mounting shown in figure 2 is preferred since it needs only a single spherical mirror and the design is neat and compact.

So far the spectrometers we have discussed have been essentially adaptations of standard spectrographs, although we have seen grating instruments have a clear superiority when faint light must be detected.

But there are two classes of instrument which are not particularly useful with photographic detection, but which pass more light than the grating spectrometer. The first class includes the interference filter, the

Fabry-Perot interferometer, and the SISAM; the second is the Michelson interferometer used as a "multiplex" instrument. Development of this field is due in large part to the group working with P. Jacquinot in Paris. Unfortunately, a discussion of principles is beyond our scope, but at least we can describe their properties; it is hoped that interference filters will be the subject of another article.

The Fabry-Perot interference filter and interferometer are different physical embodiments of the same principle and are shown in figure 4. The essence in each case is two partially-reflecting layers separated by a transparent region; the layers must be parallel to a small fraction of a wave-length. The filter used as a spectrometer can be scanned over a small wave-length region by tilting, but more often it is left fixed so as to pass a single spectral line. The spacer in the filter is an evaporated layer of transparent material, usually one wave-length thick for the line it is to pass; in the interferometer it is air and the reflecting layers are deposited on two optical flats. It is scanned by moving one of the flats mechanically, or by changing the refractive index of the gas in the spacer; this is easily done since the refractive index depends on the pressure. The interferometer passes any wave-length which "fits into" the spacer; a standing wave is set up and if the spacing equals an integral number of half wavelengths a passband occurs. Depending on the spacing, these passbands are spaced from a few tens of Angstroms to a fraction of an Angstrom; in some cases an interference filter may be used to eliminate the unwanted passbands, in others another interferometer; and sometimes the interferometer is combined with a grating whose slits are opened very wide. It is obvious that the interferometer offers formidable experimental difficulties and its use at the telescope is only beginning. Naturally nobody would be interested in it if there were no compensating advantage; this is in the fact that it passes ten to one hundred times more light than a grating spectrometer for the same resolution. Essentially, the narrow slit of the grating is replaced by a hole whose diameter can equal the length of the slit. No such difficulties attend the use of the interference filter, and it has found use in many applications, including the photography of nebulae in the light of a single spectral line.

The SISAM is a new device which is a Michelson interferometer whose mirrors have been replaced by plane gratings (figure 4). (Perhaps it should be noted that there are two types of Michelson interferometer, and that we are not concerned with the "stellar" type which has been used to measure the diameters of stars.) The name comes from the initial letters of the phrase "interference spectrometer with selection by the amplitude of modulation" in French. When the compensating plate is rotated, only

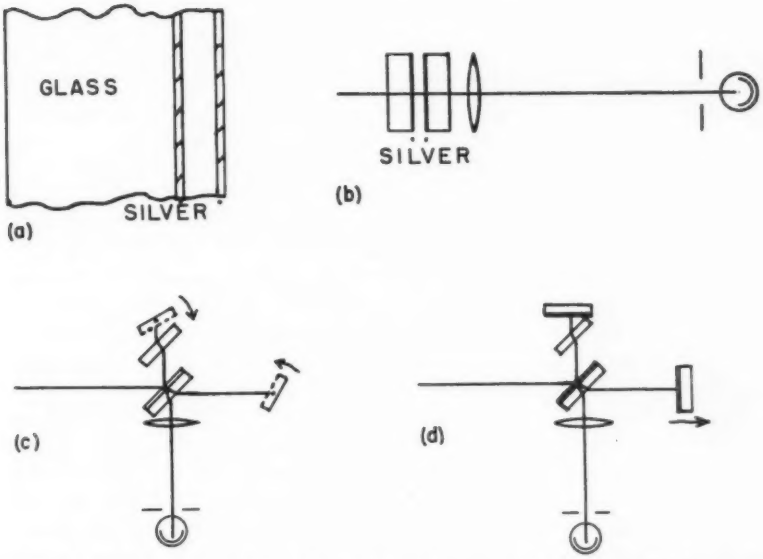

FIG. 4—(a) Interference filter; the two semi-transparent silver layers are separated by a transparent layer one wave-length thick. (b) Fabry-Perot interferometer; here the spacer is air. (c) SISAM. (d) Michelson inferometer; in the last two the diagonal mirror is half-silvered.

that wave-length which the gratings are set to reflect is modulated; it gives an alternating voltage in the detector, and all other wave-lengths give a direct voltage. Thus, the modulated wave-length can be selected from all the others by a suitable electronic circuit. Scanning is obtained by rotating both gratings together. This device passes the same amount of light as the Fabry-Perot interferometer, but is much easier to keep in alignment. Its biggest disadvantage is that the unmodulated light will increase the noise level of a photomultiplier, even though it gives no signal, and the final signal-to-noise ratio is usually no better than that of the grating. This effect does not occur with infrared detectors such as the lead sulphide cell, and so the SISAM is expected to be most useful in this part of the spectrum. It is too new to have been applied to "outdoor" spectroscopy yet, but such application will be made before long.

It is obvious that a great improvement in spectrometers could be made if the whole spectrum could be observed all the time, instead of scanning so as to detect one wave-length at a time. The obvious solution is to

provide a large bank of detectors side by side, one for each wave-length; but each detector needs its own amplifier and indicator, and the scheme is not practical. This type of system is called "multiplex", and even though this embodiment is not practical, there is another which is: the Michelson interferometer (figure 4) from which the SISAM was derived. It passes just as much light as the SISAM or Fabry-Perot interferometer, of course, but also permits all wave-lengths to be measured simultaneously. It is scanned by moving one of the mirrors over a certain range; the record produced looks like a confused jumble and does not at all resemble the spectrum, but in fact it is the Fourier transform of the spectrum. The inversion of the transform to produce the original spectrum is difficult, but it can be done, usually with the help of an automatic computer. As with the SISAM, there is no advantage gained with photomultiplier detection, but the method is promising for the infrared and several astronomical applications were reported at the colloquium referred to at the end.

What can we conclude from this brief look at techniques which may be of use in astronomical spectroscopy? It seems that the photoelectric method may have application to some problems now studied by photographic means, especially where intensity measurements are important and the sources are not too faint. It will supplement the photographic method, not replace it, just as it has in stellar intensity measurements and auroral spectroscopy.

We have mentioned few names and given no references, but some may be found in the bibliography which gives a selection of papers bearing on the subject.

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STELLAR POPULATIONS*

By Martin F. McCarthy, s.j.
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In this paper we shall speak of stellar populations and the role they have played in helping us to understand more fully the nature of the universe around us. The better to appreciate the importance of population studies we should examine very briefly the picture of our galaxy as it could be sketched before 1944 when Baade of Mount Wilson introduced the concept of stellar populations.

At the turn of the century the statistical studies of Seeliger, Schwarzschild and Kapteyn provided a model of our galaxy in which the sun occupied a central or nearly central position with star density dropping off in all directions at increasing distances from the sun. Then in the second decade of the present century, Shapley in a brilliant series of papers demonstrated from studies of novae, Cepheid variables and globular clusters that our sun is not indeed at the centre or hub of the universe but rather far out in the "suburbs", out near the rim of the Milky Way. He showed that the true centre lay some 30,000 light-years away in the direction of the star clouds of Sagittarius. This work was extended and amended by the discovery by Trumpler at Lick that there are large clouds of dust and gas in the galaxy which cut down and redden the light from obscured stars and clusters. In 1927 Oort of Leiden announced the discovery of galactic rotation, and showed that the stars in the vicinity of the sun are revolving about the centre once every 200,000,000 years and that the mass of the galaxy amounts to some 100 to 200 billion solar masses. This then was the picture of our galaxy: a huge mass of stars, dust and gas some 100,000 light-years in length and about 10,000 light-years at its greatest width near the galactic nucleus in Sagittarius. We knew approximately the whereabouts of the sun and its neighbours in space, but because we were "immersed" in the Milky Way, we could no more hope to map the structural details of our galaxy with tools then available than a person standing at the foot of Little Saanich Mountain on a foggy evening could hope to draw an accurate map of downtown Victoria.

Since astronomers found themselves limited in their explorations inside the galaxy, they began to look outside, to study the structure of other galaxies where dust and gas did not obscure.

*An address to the Victoria Centre, R.A.S.C.

In 1936 Hubble classified the galaxies into three broad groups: spherical or elliptical galaxies which made up 17 per cent. of his sample, spiral systems, by far the most common type with 80 per cent. of the total, and irregular galaxies which numbered only 3 per cent. of the galaxies observed. His studies showed two very important differences between the spiral and elliptical galaxies; spiral galaxies contain large quantities of dust, while elliptical galaxies show little, if any. Secondly, on photographs obtained with large telescopes, spirals could be identified as systems of stars, whereas no elliptical galaxy could be resolved even with the 100-inch Mount Wilson reflector. Further, even in the nearest spiral, M 31, the Andromeda galaxy, stars in the arms could be resolved whereas those in the central portions could not.

Then in 1944 Baade using red-sensitive plates succeeded, with magnificent observational care, in photographing individual stars in the central portion of M 31 and went on to resolve its two elliptical companions M 32 and NGC 205. Baade's photographs showed that the brightest stars in the newly resolved systems were not blue stars, as the brightest stars in the arms had been, but rather red stars, red giants similar to those found in globular clusters in our own Milky Way. Thus the stars were distinguished by Baade into two different population systems: Population I, typical of spiral arm regions, and Population II, typical of elliptical galaxies, the nuclei of spiral systems and the globular clusters. These features were augmented in further studies made at the same time and are summarized in Table I.

TABLE I

Population I	Population II
Galactic (open) clusters	Globular clusters
Brightest stars: blue supergiants	Brightest stars: red giants
Abundant gas and dust	Little or no dust and gas
Cepheid variable stars	RR Lyrae and W Virginis variable stars
Emission nebulae	

As often happens after a "breakthrough" such as this one by Baade, there are almost simultaneously marked advances in several directions. All astronomy feels the impact, just as today all science experiences the excitement and views with eager interest the new horizons opened by our first earth satellites. Let us see how this "breakthrough" by Baade led to the discovery of the location of the spiral arms of our galaxy.

Morgan and his associates had shown that the bright blue stars do not form a disk-like, uniform distribution throughout the galactic plane; rather they lie in three lanes which may well be segments of the spiral arms of our Milky Way. These arms range in width from 900 to 1500 light-years

and the average interarm distance is estimated to be about 4500 light-years.

A further attempt to trace the galactic spiral arms was undertaken in 1957 by Münch. He measured the absorption by interstellar gas of the light from stars at varying distances and in different directions in the plane of the galaxy. He found that the gas lanes had the same distance and direction as the lanes of blue stars mapped by Morgan and his colleagues.

Shortly after Baade's announcement of two stellar populations, van de Hulst of Leiden suggested that one might observe radio waves emitted by interstellar hydrogen at a wave-length of 21 centimetres. This prediction was confirmed in 1951 by Ewen and Purcell at Harvard, by Oort and Muller at Leiden and by Christiansen and Hyndeman in Australia. The first complete mapping of the cool hydrogen at 21 centimetres was made by the Dutch radio astronomers whose results indicate a strong concentration in those regions which contain the blue giants observed by the Yerkes astronomers and the interstellar absorption lanes marked out by Münch.

We have now progressed sufficiently far in tracing the arms in our galaxy that they can be named. The first arm is called the "local arm" or the Orion arm; our sun appears to be located at the inside or inner edge of this arm and it includes also the Orion Nebula and the North American Nebula in Cygnus. The second arm lies at a great distance from the sun and because its most prominent feature is the great double cluster h and χ Persei, it has been named the Perseus arm. The third spiral arm is called the Sagittarius arm. It lies in the direction of the galactic centre and is much closer to our sun than to the galactic nucleus. This arm with its clouds of absorbing dust and gas may be the reason why it is difficult to observe the bright central nucleus of our galaxy. Very recently an excellent description of evidence for spiral arm structure in the galaxy has appeared in a letter by Bok, published in the April 1959 issue of *The Observatory*.

Perhaps the finest illustrations of the characteristic differences between stellar populations can be seen in an analysis of two kinds of objects, the globular clusters and the galactic or open clusters. Globular clusters are very rich stellar groups containing tens or even hundreds of thousands of members. These clusters are rounded and show a high concentration of stars towards the centre. They are not dominated by a few bright stars and their brighest stars are red giants. Shapley pointed out that almost all globular clusters lie in that part of the sky which contains the galactic

centre. Open or galactic clusters are far less rich in their appearance; they show little or no central concentration, have relatively few stars (ten to a few hundred) and feature bright blue supergiant stars which frequently account for almost one-half the total light of the cluster. Open clusters tend to avoid the direction of the galactic centre and are prominent objects along the plane of the Milky Way. They are often imbedded in dust clouds, as in the case of NGC 2264 (see figure 1).

FIG. 1—The region of NGC 2264, from the Ross-Calvert *Atlas of the Milky Way*.

That we may learn more about the roles each group plays in the structure of our galaxy, let us consider briefly the famous Hertzsprung-Russell diagram, in which for each star intrinsic brightness or luminosity is plotted against spectral type, or surface temperature, or colour difference. Figure 2, taken from a paper by Sandage (*Stellar Populations*, 1958)

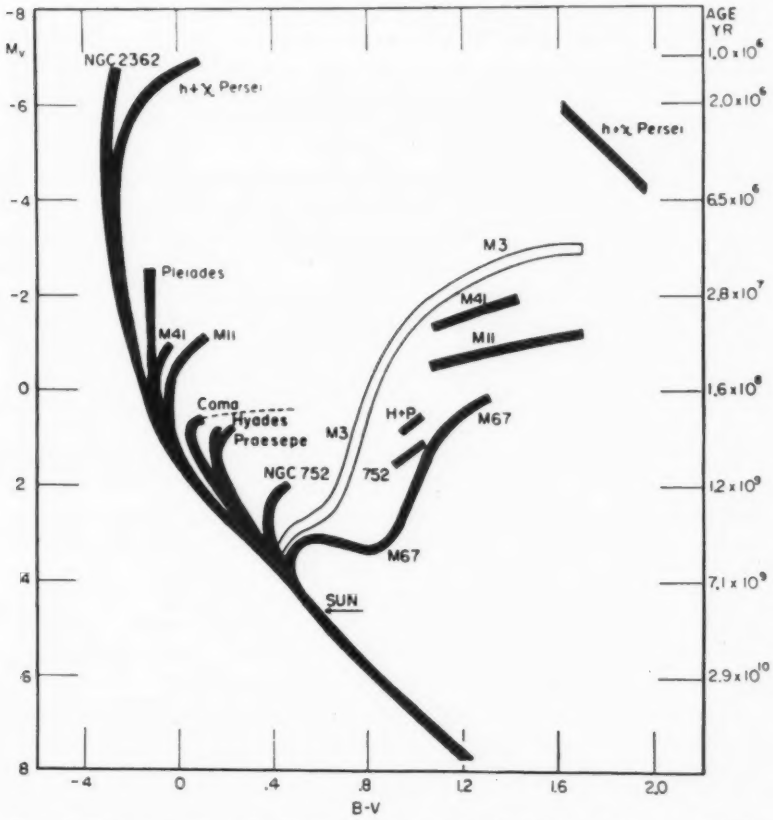

FIG. 2—Hertzsprung-Russell diagram for ten galactic clusters and one globular cluster. (Sandage, *Stellar Populations*, p. 42.)

shows a composite diagram for ten galactic clusters and one globular cluster, M 3. Here luminosity (left-hand ordinate) is plotted against colour difference (*B-V*). The blue (hot) stars will be represented on the left side of the diagram, the red (cool) on the right; the more luminous

stars in the upper part, the less luminous in the lower. The branch running from upper left to lower right is called the main sequence; to the right of this lies the red giant or supergiant branch. Note that many galactic clusters reveal a gap between the main sequence and giant branches (the Hertzsprung gap), and that the brightest stars in galactic clusters are blue stars. Consideration of the masses involved and the rate of radiation leads to the conclusion that these supergiant stars must have been formed very recently, and comparative studies of many galactic clusters indicate that the younger clusters will lie closer to the top of the diagram and contain the more luminous blue supergiants. The right-hand ordinate in the figure gives the age that corresponds to the main-sequence termination points.

The Hertzsprung-Russell diagram for the globular clusters shows a quite different pattern. There is no Hertzsprung gap; the brightest stars are not the blue supergiants but the red giants. The present picture of stellar evolution indicates that the stars evolve away from the main sequence at a point not very far above the position of our sun on the sequence. As stars leave the main sequence they undergo a marked increase in brightness, while the surface temperature decreases. After reaching the tip of the giant branch at the upper right the evolving stars reverse their direction, decrease in brightness and move along the horizontal branch to the left.

Theoretical studies by Hoyle, Salpeter, Sandage, Schwarzschild, and Spitzer (*Stellar Populations*, 1958) indicate that a group of stars of uniform age and composition will fall on a sequence resembling the Population II portrait of a globular cluster, depending on the original amount of matter assumed for the stars, and provided a period of 5×10^9 years is allowed for the stars to develop. From the close resemblance of such theoretical diagrams to those observed for the globular clusters one may infer with some certainty that the stars in such clusters must be very old indeed, about 5×10^9 to 8×10^9 years.

Further evidence for the relative ages of globular clusters and galactic clusters comes from a study of the dynamics of these systems. One can calculate the time required to disrupt a cluster through the tidal distortions from gravitational sources. The results of such calculations show that the massive globular clusters can withstand the shearing forces for many billions of years, whereas the less massive galactic clusters are continually being torn apart as the galaxy revolves, so that most galactic clusters do not grow older than about 0.5×10^9 years. It thus appears that the stars of Population II were formed some 5×10^9 to 8×10^9 years ago and that the stars of Population I have been forming ever since.

There are two interesting examples of members of Population I that

are believed to be very young. The first is the cluster NGC 2264 (see figure 1), an open galactic cluster studied by Walker. From the Hertzsprung-Russell diagram there is evidence that the stars of this cluster are only 3 million years old, and that younger stars are still in the process of joining up as members of the cluster. Such faint stars do not fall on the main sequence portion of the diagram as do the brighter members of the cluster, but are located above it, perhaps indicating that they may even now be contracting gravitationally from the interstellar medium.

A second interesting member of Population I was discovered by Herbig of Lick Observatory. In studies of faint stars in the Orion Nebula he noticed two stars that suddenly brightened up a few years ago and that have remained approximately constant in brightness ever since. Perhaps these are stars which have veils of carbon covering their surfaces, or they may be stars that have been lurking behind clouds of obscuring matter which moved away, or (and this is most exciting) we may be observing here a stage in the actual formation of stars.

It is of interest to compare the populations in two different regions of our galaxy, first toward Sagittarius and then toward Carina. In the direction of the large Sagittarius cloud lies the centre of our galaxy, some 30,000 light-years away. In clear regions of this cloud Baade finds a total absorption of only 2.8 magnitudes at a distance of 8.2 kiloparsecs, whereas outside the clear region there is a very dense network of overlying dark clouds which absorbs 5 or more magnitudes and hides from us the actual centre of the galaxy. In Sagittarius we find numerous globular clusters, but no hydrogen emission nebulae and no galactic clusters except those few which lie between the sun and the Sagittarius arm. The Schmidt plates taken by Minkowski at Palomar show many faint planetaries, and Nassau and Blanco have recorded as many as 1850 M giants per square degree in the direction of Sagittarius.

Some 70° from Sagittarius in the "hidden" quadrant of the Milky Way lies the constellation of Carina. The absorption in this part of the sky is unusually small. Photographic studies by the author of the colours of the Cepheids in the Carina region show a mean absorption of 0.5 magnitude per kiloparsec, while recent photoelectric observations by Irwin indicate a value of 0.4 magnitude for the same region. OB and Wolf Rayet stars abound near the Eta Carinae region. Very many hydrogen emission sources have been catalogued for this region, and Trumpler noted that it contained no globular clusters but some 21 open or galactic clusters. All these are of Population I type.

Bok has made a study of the distribution of variable stars in these two directions. In the direction of Sagittarius there is an almost complete absence of classical Cepheids, yet an abundance of RR Lyrae stars and

W Virginis variables so characteristic of Population II. Of the direction of Carina he states that "nowhere along the Milky Way does one find a purer sample of Population I stars".

In 1954 Miss Roman showed from photoelectric studies at Yerkes and McDonald Observatories that the intensity of ultraviolet light from certain high-velocity stars is stronger than that from low-velocity stars of the same spectral class. This ultraviolet excess has been interpreted as a measure of the ratio of the metals to hydrogen. Initial studies of the ultraviolet excess in a number of globular clusters have led Sandage and others to believe that the differences between the populations may consist for the most part in differences in the initial chemical composition. The suggestion is made that Population II objects may have been formed from materials with low metal concentration while the Population I objects were formed from metal-enriched material thrown off by the older stars. Some globular clusters appear to differ strongly in chemical composition from the rest and may belong to an intermediate Population II or even to the disk Population. Oort has emphasized that it is by no means certain from presently available data whether the differences between the globular clusters represent merely differences in age or whether even in the first stages of our galaxy some appreciable change in the chemical composition may have occurred.

It may be noted that several of the very prominent galactic objects are not listed in Table I. The reason for this omission is not that these objects are so rare that they are unimportant but rather that in a first survey it could not be known with precision where or how these objects should be fitted into the scheme. In any successful classification process one begins with the extremes, and only later when these are clearly defined, can an attempt be made to fill in the interior details. So in the 15 years that have passed since Baade's announcement of two fundamental stellar populations many refinements, extensions and additions have been made. These extensions have not been the work of one man but of many astronomers in all parts of the world working together to advance further our knowledge of the structure and development of our galaxy. One feature of these studies has been the recognition of the importance of the disk population as distinct from the halo and arm populations. This has been achieved by a correlation of the kinematic, physical and spatial properties of the objects that make up the different population groups. Another feature of the developments since 1944 has been the successful application of the concept of stellar evolution to the problems of stellar populations.

An hypothesis sketched by Oort delineates the manner in which our galaxy may have developed. After the beginning there was a thin gas

which expanded. Later the internal gravitational force became strong enough to overcome the velocity of expansion and aggregates of matter started their development as separate and discrete units called protogalaxies. The still irregular mass of the protogalaxy was marked by internal motions and turbulence but with a gravitational force large enough to start contraction. Lumps of matter contracted rapidly and condensed into stars. As a result of the mixing currents the protogalaxy rotated faster and began to flatten out leaving some of the old stars behind. Finally it flattened into a thin disk in which new stars could condense from the dust and gas, enriched with some of the elements developed and thrown off by the older stars.

The theoretical description of Oort can serve as an illustration of the five stellar populations accepted today. It should be noted that this description is an illustration, not a proof, nor in any sense a limitation to subsequent theoretical or observational researches. The old stars left behind are the stars of Population II. Stars of extreme Population II make up the galactic halo. The newest stars are the ones now forming in places where there is still dust and gas; these we may call the stars of extreme Population I. Between these are the Intermediate Populations and the very important and the most massive of the population groups, the Disk Population. These five make up our own spiral galaxy, the Milky Way.

In May 1957 a thorough discussion of the problems of Stellar Populations, both theoretical and observational, was held at Vatican City sponsored by the Pontifical Academy of Science and the Vatican Observatory. Table II presents the classification of Stellar Populations adopted at these meetings. Some typical members of each of the five Population groups are listed; these typical members define the classification finally approved by the Conference. The additional entries are taken from the paper presented by Oort at the Conference and serve to illustrate some of the differences in properties of various groups of stars; $|\bar{z}|$ gives the mean distance from the galactic plane in parsecs; $|\bar{Z}|$ shows the random average velocity in this co-ordinate. Succeeding lines give the concentration towards the galactic centre, the space distribution, the heavy element density, in terms of unity for hydrogen, based on data presented by Schwarzschild, the age, and the total mass estimated for each of the Populations. Oort has noted that the data presented have been compiled from various sources and that some of them are very uncertain. Nevertheless they form a fine summary of the present picture of the known features of stellar populations and invite further research.

Oort has summarized in *Stellar Populations* (1958) the conclusions reached by the participants at the Vatican conference, and some of the problems yet unanswered. The following is a paraphrase of his summary.

TABLE II

CLASSIFICATION OF STELLAR POPULATIONS, VATICAN CONFERENCE 1957

	Halo Population II	Intermediate Population II	Disk Population		Older Population I	Extreme Population I
Typical Members	Subdwarfs	High-velocity stars, $z>30$ km./sec.	Stars of galactic nucleus		A-type stars	Gas Young stars associated with present spiral structure
	Globular clusters, high z-motion	Long-period variables, $P < 250$ days, earlier than M5e	Planetary nebulae Novae		Strong-line stars	Super-giants Cepheids T Tauri stars
	RR Lyrae stars, $P > 0.4$ day		RR Lyrae stars, $P < 0.4$ day Weak-line stars			Galactic clusters of Trumpler's class I
$\lvert\bar{z}\rvert$ (parsecs)	2000	700	450	300	160	120
$\lvert\bar{Z}\rvert$ (km./sec.)	75	25	18	15	10	8
Concentration toward centre	Strong	Strong	Strong	?	Little	Little
Distribution	Smooth	Smooth	Smooth	?	Patchy, spiral arms	Extremely patchy, spiral arms
Heavy element density (Hydrogen = 1)	0.003	0.01		0.02	0.03	0.04
Age (10^9 years)	6	6.0 to 5.0	5	1.5 to 5	0.1 to 1.5	0.1
Total Mass (10^9 ⊙)	16	47			5	

Conclusions:

1. The Hertzsprung-Russell diagrams of clusters give empirical information on the evolution paths followed by stars of different initial masses and various chemical compositions.
2. The differences in chemical composition of different types of stars are principally due to differences in the composition of the interstellar medium from which they were formed.
3. During the life of the galactic system the interstellar composition appears to have changed considerably, having gradually been enriched in heavy elements.
4. The large compositional differences between various globular clusters indicate that much of the enrichment must have taken place in the early stages of the system's formation before the gas had contracted to a disk.
5. Most galactic clusters do not grow older than about 0.5×10^9 years.
6. The ages of stars which have left the main sequence may be estimated from colours and luminosities. Certain spectral criteria may be employed to indicate ages for stars near the main sequence.

Problems needing further research:

1. Has the change in chemical composition been the same in all parts of the galactic system?
2. Can chemical compositions be determined adequately by one parameter?
3. Can supernovae of types I and II have sufficed to cause the changes that have taken place in the interstellar gas? Which other stellar types may have contributed to this process?
4. What is the cause of the striking difference in spectra, Hertzsprung-Russell diagrams and variable stars among the various globular clusters all attributed to the halo?
5. What are the features of the Hertzsprung-Russell diagrams for those globular clusters with large heavy-element content to which Mayall and Morgan have drawn attention?
6. What causes the differences in stellar composition between globular clusters and elliptical galaxies?

How fruitful then has been the original suggestion of Baade that there are two basic populations among the stars of our galaxy, one characteristic of the inner, the other of the outer parts of a spiral galaxy. In

recent years the notion of the disk population in which the arm objects are imbedded and above which (and through which?) the halo objects extend has been of great value in efforts to explore the complexities of galactic structure. Future research on problems of stellar distribution, stellar motions, spectroscopic and photometric observations aided and advanced by new tools such as the radio telescope and the image tube, bid fair to provide us with an ever clearer picture of our own galaxy, the Milky Way.

Reference

Stellar Populations, 1958, edited by D. J. O'Connell, S. J., North Holland Publishing Company, Amsterdam.

CANADIAN SCIENTISTS REPORT—XVIII

THE LABORATORY EXCITATION OF METEORITIC SPECTRA IN SHOCK TUBES*

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Meteor trains have frequently been used to provide information upon conditions in the upper atmosphere and upon processes of energy transfer between the atmosphere and the meteoroid which take place during its flight. One important aspect of the train is the spectrum of its luminosity and until recently it has only been possible to make progress towards an understanding of processes taking place in the train through observations upon meteors in flight. The amount of data which can thereby be collected is limited by the frequency of occurrence of meteor trains and of the efficiency of observing them.

In an effort to bring meteor physics into the laboratory and thereby to subject it to controlled experiment, observations have been made over the past few years upon high speed pellets fired over special ballistic ranges into gases at a variety of pressures and at velocities somewhat below those of the slower meteors (1, 2, 3, 4). Phenomena such as heat transfer, ablation, ionization and excitation of luminosity have been studied in the ballistic pellet experiments.

It is the purpose of this paper to describe a further set of experiments which bring other aspects of meteor physics into the laboratory. These concern shock excitation of powdered meteorites.

In a current research programme on shock excitation of powdered solids (5), a number of the physico-chemical aspects of the interaction between the transient heat pulse of a helium driven shock wave in argon and powder particles (metallic oxides, metals, organics) are being studied (6, 7, 8) by spectroscopic and other means. When the hot gas behind the shock wave reflected at the terminal window of the shock tube interacts with the particles of the sample placed at the window, an intense flash of luminosity occurs for about 2 milliseconds. Spectroscopic studies have shown that an *atomic* vapour is ablated from the particles by the

*A summary of this article was presented at the session for papers at the Annual Meeting, March 14, 1959.

shock wave. If conditions are suitable, association of atoms can occur in the vapour to form molecules which emit a characteristic spectrum. Ablation (8) and surface chemical changes (7) are the two most pronounced effects on the particles of the shock treatment.

Experimental. Four specimens of meteoritic material were subjected to shock excitation and are listed in Table I. The first three were purchased from the American Meteorite Museum, and the fourth was kindly donated by the Department of Geology, University of Western Ontario.

TABLE I

METEORITIC SPECIMENS USED (9, 10)

Name	*Type*	*Date of Fall or Find if Known*
Dimmitt (Texas)	Stone Chondrite	Fall prior to 1947
Odessa (Texas)	Iron Coarse Octahedrite	Fall prior to 1922
Potter (Nebraska)	Stone Grey and Black Chondrite	Found 1941
Dresden (Ontario)	Stone Grey Chondrite	Fell 1939

A few grammes of each meteorite specimen were ground up with a clean pestle in a clean mortar.

The powder was sieved (100 mesh) to a controlled average particle size of about 0.15 mm. diameter and about a gramme of each specimen was placed, for each respective experiment, at the window end of the low pressure section of the shock tube. It consists of two lengths, 3 ft. and 9 ft. long respectively, of 2-in. internal diameter copper tubing. The 3 ft. high pressure chamber was supplied with helium at a pressure of about 200 lbs./sq. in. It was separated by a mylar diaphragm from the 9 ft. low pressure section which was filled with argon at a pressure of a few ounces per sq. in. and was terminated with a quartz window through which luminosity of the shock excitation process could be observed. The tube was aligned along the optical axis of a Hilger E517 f/4 spectrograph. Kodak Royal Pan film and Tri-X plates were used to photograph spectra of the transient luminosity at reciprocal dispersions of 25 A./mm. (λ3700) 100 A./mm. (λ5000) and 200 A./mm. (λ6520). Iron arc comparison spectra enabled wave-length measurements and identifications to be made to within about 0.5 A.

Each exposure was initiated by breaking the mylar diaphragm with an electro-magnetically driven plunger. The helium driven shock wave in argon was thereby propagated into the low pressure section at a Mach number (the ratio of shock wave velocity to the velocity of sound in argon) which was determined by the initial pressure ratio, temperature ratio and molecular weight ratio across the diaphragm. The high gas temperature immediately behind the shock front is also determined by these quantities. Upon reaching the window at the end of the tube, reflection of the wave occurred with a consequent approximate doubling of the gas temperature behind the shock front. It is thus the high temperature reflected wave which had the strongest interaction upon the powder particles and caused severe ablation (7, 8) of the luminous, essentially atomic, vapour. The luminosity has been measured to last about 2 milliseconds during which time the spectral record was photographed.

Results. A sequence of spectra of the luminosities from the shock excited Dresden Meteorite specimen are shown in figure 1 for a series of

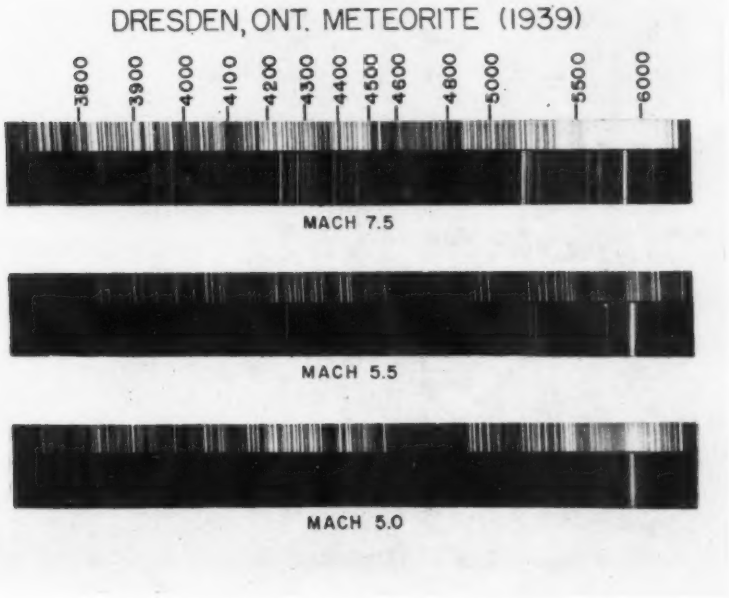

FIG. 1—Dresden meteorite spectra at a variety of Mach numbers. (*Top spectrum is iron arc comparison spectrum*)

increasing Mach numbers (and reflected wave temperatures). It is seen that the spectra are all of *atomic* lines whose richness increases with increasing Mach numbers.

This result is typical of that obtained with all of the meteorite specimens whose shock excited line spectra at Mach 7.5 (12,000°K. in reflected wave) are reproduced in figures 2 and 3.

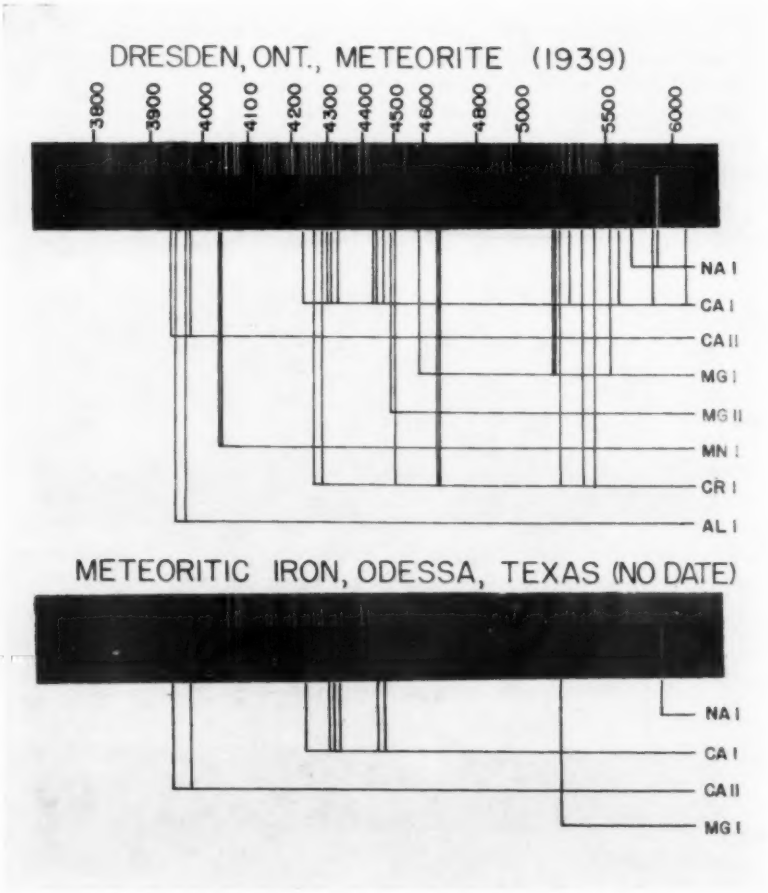

FIG. 2—Shock excited spectra of meteorite specimens at Mach 7.5. (*Top spectrum is iron arc comparison spectrum*)

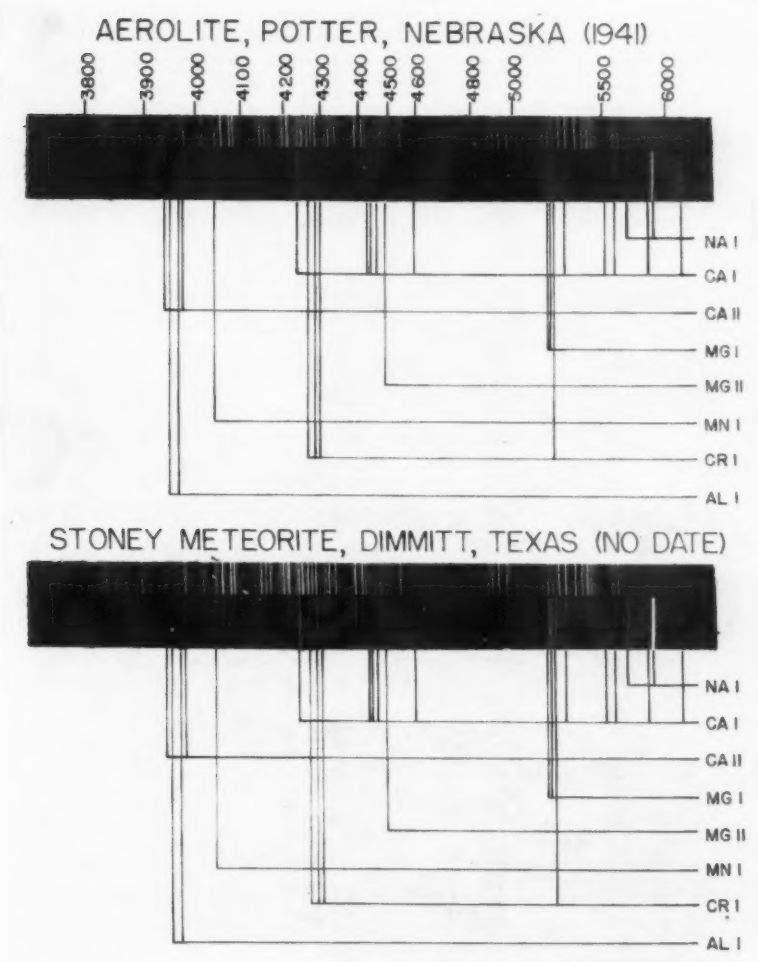

FIG. 3—Shock excited spectra of meteorite specimens at Mach 7.5.
(*Top spectrum is iron arc comparison spectrum*)

Identification of the spectra was made and multiplets represented in the 237 lines involved are listed comparatively in Table II, in which notation for multiplets, multiplet number and excitation potential follow "A Multiplet table of Astrophysical Interest" (11).

TABLE II

MULTIPLET IDENTIFICATIONS

Element	Multiplet Number	Excitation Potential	Meteorite Specimen				Reported In Millman's Table
			Dimmitt	Odessa	Potter	Dresden	
FeI	1	2.44	x	x	x	x	x
	2	2.85	x	x	x	x	x
	3	2.98	x	x	x	x	x
	4	3.24		x	x		x
	15	3.24	x	x	x	x	x
	16	3.38	x	x	x	x	x
	18	3.95		x			x
	19	3.87		x			x
	20	4.18		x	x		x
	36	3.92		x			
	37	3.87	x	x	x	x	x
	38	4.15	x		x		x
	39	4.25	x	x	x	x	x
	41	4.40	x	x	x	x	
	42	4.45	x	x	x	x	x
	43	4.58	x	x	x	x	x
	44	4.57		x			
	45	4.75		x			
	62	4.18		x			
	68	4.95	x	x	x	x	
	71	5.05	x	x	x	x	x
	72	5.30		x			
	114	4.80	x				
	115	4.93	x		x		
FeI	152	5.35	x	x	x	x	x
	276	5.77			x		
	278	5.80		x	x		
	318	5.35	x	x	x	x	x
	319	5.55		x			
	350	5.59		x	x	x	
	354	5.80		x	x	x	
	355	5.79		x	x		
	356	5.83		x			
	357	5.82		x			
	359	5.87	x		x		
	383	5.35	x	x	x	x	
	409	5.60		x			
	518	5.86				x	
	553	5.56	x				
	554	5.90		x	x	x	
	558	6.26		x			
	559	6.25		x			
	686	5.60	x	x		x	
	753	6.11				x	
	821	6.25	x		x		
CrI	1	2.89	x		x	x	x
	7	3.31	x		x	x	x
	10	3.65	x			x	
	18	3.31	x		x	x	
	21	3.65				x	
	22	3.82	x		x		x

TABLE II (*continued*)

Element	Multiplet Number	Excitation Potential	Meteorite Specimen				Reported In Millman's Table
			Dimmitt	Odessa	Potter	Dresden	
CaI	2	2.92	x	x	x	x	x
	3	3.89	x		x	x	x
	4	4.66	x	x	x	x	x
	5	4.75	x	x	x	x	
	20	4.51	x				x
	21	4.72	x		x	x	x
	22	4.86	x		x	x	x
	23	5.21	x		x		x
	25	5.53		x			
	47	5.03	x		x	x	x
	48	5.16	x		x		
CaII	1	9.21	x		x	x	x
MgI	1	2.70	x				x
	2	5.09	x	x	x	x	x
	9	6.56	x		x	x	x
	11	6.95			x	x	x
	14	7.16				x	x
MgII	4	19.19	x		x	x	x
MnI	2	3.06	x		x	x	x
	5	5.16	x				x
	31	5.37	x				
	36	5.68	x				
AlI	1	3.13	x		x	x	x
NaI	1	2.10	x	x	x	x	x
	6	4.27	x	x	x	x	x
SrI	2	2.68	x				
SrII	1	8.64	x				
BaI	2	2.23	x		x		
BaII	1	7.79	x		x	x	

A complete list of identifications, which is somewhat cumbersome, is available from the authors on request.

Discussion. There is excellent agreement between the lines and identifications of Table II and those collected by Millman from his own and other meteor spectra (12). This agreement, though not unexpected, is all the more interesting when the conditions under which meteor spectra are obtained are compared with those obtaining in the shock tube. Meteor spectra which have been photographed arise through ablation from the small ($\sim$ 1 cm. diameter or less) fragile porous solids of low density as they collide at high speed (70 km./sec.) with individual atoms and

molecules in the upper ($\sim$ 100 km.) atmosphere. The meteorite specimens are of a much more dense material of different, generally known, mineral-like compositions. The meteorite spectra were excited thermally (see below) and the close similarity in the resulting spectrum to those of the meteors may have some bearing on the discussion of the origin of meteors and meteorites (13).

The excitation of luminosity from meteors in the upper atmosphere and of the meteorite specimens in the shock tube arise through energy transfer processes between the atmosphere which envelops the solid particle involved (both are of comparable size) and the particle itself. In the case of meteors, the energy transfer processes, which result in ablation of matter and emission of luminosity, are well described by the model of Whipple (14) in which the energy transferred is measured by the total kinetic energy destroyed per second upon the surface of the meteoroid by collisions with individual atmosphere gas molecules. In the case of the shock excitation of powdered meteorites, however, recent direct measurements of ablation of material from powdered metals which have been shock excited by reflected helium driven shock waves in argon over the range 760–9700 mm. mercury of transient pressure and over the range 293 °K.–10,200 °K. of transient temperature have shown that the conventional convective heat transfer model of aerodynamics (15) appears to be operative here (8). In this model, the energy transfer is proportional to the temperature difference between the hot gas and the solid particle enveloped by it. This result is not surprising in view of the high transient pressures involved. It would be interesting to repeat the experiments at much lower transient pressures, to overlap the conditions in the ballistic pellet experiments of Thomas and Whipple (4), in which the meteor equation of energy transfer appeared to hold, and to see if any change in the spectrum occurs. Experiments of this nature are in process.

Finally it should be pointed out that at no stage of our experiments with powdered meteoritic specimens did molecular spectra, similar to those shock excited at low Mach numbers from metallic oxides (6), appear; not even at the lowest Mach numbers. Undoubtedly this indicates that not even at the lower temperatures, which would support the formation of diatomic species, were the constituents of physically stable diatomic species present in the vapour. The only recent report of molecular spectra in meteor trails (16) was of excitation of N_2 through which the meteoroid travelled.

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NOTES

Chant Medal and Service Award

The Royal Astronomical Society of Canada offers two awards—the Chant Medal and Service Award—for outstanding contributions to astronomy or to the Society. The Committee for the Chant Medal has expressed concern over the lack of nominations received in the past two years.

The Chant Medal, established in 1940 in honour of the late Professor C. A. Chant, is a silver medal which may be awarded annually "to an amateur astronomer (not necessarily a member of the Society) resident in Canada, the Award to be made on the value of the work which he has carried out in astronomy and closely allied fields of original investigation". A deserving recipient is selected by a Committee of three, appointed by the National Council, from completed nominations signed by the nominee or by close associates. Nomination forms are available from the National Office of the Society and should be submitted before the end of the calendar year. It is requested that if the nominee is a member of a Centre, the nomination be forwarded to the National Secretary with the approval of the officers of that Centre.

The terms of award of the Chant Medal specifically state that "the Medal is not awarded on the basis of work done for, or to advance the interests of the Society, valuable as this work is," but "to encourage contributions to science itself". It is for this reason that the National Council has recently established the Service Award.

The Service Award is a small bronze plaque which may, upon the recommendation of a special Committee of the National Council, be awarded to members of the Society who have performed outstanding service to a Centre or to the National Society. Centres are requested to limit nominations for this Award to one every three years on the average.

The intended purpose of this announcement is to bring the conditions pertaining to these two Awards to the attention of all members of the Society and to encourage all officers of the Society to suggest more nominations than have recently been made.

J. E. Kennedy, *National Secretary.*

Obituary: Alfred Edward Johns

Alfred Edward Johns died suddenly at his summer home in Haliburton on July 20, 1959, in his 76th year.

Dr. Johns was born in Exeter, Ontario. After completing his elementary education there, he went to the University of Toronto where he took his B.A. in Mathematics in 1907, winning the Gold Medal in Mathematics and the Edward Blake Scholarship in Mathematics and Moderns. He completed his M.A. in Mathematics in 1908.

Upon a strong conviction of a call to service he studied Theology at Victoria College and was ordained to the ministry of the United Church of Canada (Methodist Church) in 1910. He then proceeded to West China University where he was Professor of Mathematics from 1910 until 1926. He returned to Canada in 1926 and became Professor of Mathematics at Brandon College from 1927 until 1931 at which time he moved to Hamilton and joined the McMaster Mathematics Department. He completed the requirements for the Ph.D. Degree at the University of Toronto in 1935 and became head of the McMaster Department in 1946.

Dr. Johns' interests were wide but the two closest to his heart were the Missionary Activities of the United Church of Canada and the Royal Astronomical Society of Canada. He was Chairman of the Missionary and Maintenance Fund of the Hamilton Presbytery and also President of the Hamilton Centre of the R.A.S.C. (1936 and 1937) before becoming National President (1945 and 1946).

Dr. Johns will long be remembered by his students, associates and friends as a sympathetic and understanding teacher, as a dedicated minister and counsellor and as a warm friend. Gone is the mathematician, astronomer, minister, and teacher but his influence for good lives on.

W. J. McCallion

Error in the 1959 Observer's Handbook

The *dates* of the minima of Algol are one day early, commencing with the entry for Sun. Nov. 22, and continuing for the rest of the year (pages 53 and 55). Thus Algol will be at minimum on Nov. 20 at 14:01, Nov. 23 at 10:50, Nov. 26 at 7:39 and so on.

It is to be noted that the numerical values of the *time* are correct, but that the minima occur a day *later* than listed for the last three entries of November and all of December.

The Editor

REVIEW OF PUBLICATIONS

The Astronomer's Universe by Bart J. Bok. Pages 107; 5¾ × 9 in. Melbourne University Press, Australia, and London and New York, Cambridge University Press, 1959. Price $3.75.

This book is based on a series of lectures given at Canberra University College and the University of Sydney, 1957–58 by Dr. Bart Bok, Director of Mt. Stromlo Observatory. It combines those ideas about the solar system which are of greatest interest to the general reader with the current ideas of the sidereal universe. Dr. Bok has long been known for his ability to state sound scientific facts in a manner which makes interesting listening or reading.

The four sections of the book deal with problems on the solar system, stars as individuals, the Milky Way system, and ages and evolution. The discussion ranges from the well-balanced summary of theories of origin of the solar system to globules and proto stars. Helpful to many will be the "Select Bibliography" at the end which contains many background references on various fields. The sixteen plates scattered throughout the book are of very high quality, some even surpassing in contrast effects those in the more detailed book by Bart and Priscilla Bok, "The Milky Way".

It is interesting to have throughout this book a certain emphasis on astronomy in the southern hemisphere. This includes the many references to Australian research in both optical and radio astronomy, the emphasis on the Magellanic Clouds, the description of the most brilliant parts of the Milky Way passing through the zenith in southern hemisphere countries, and the fact that "the solution to several of the key problems relating to the structure of our Milky Way system lies in the southern hemisphere". Because so much of astronomy in the past has been concentrated in the northern hemisphere it is refreshing to have a book of widespread popular interest with a southern hemisphere flavour.

This book is an excellent answer to the problem frequently posed astronomers by interested and intelligent laymen—to recommend an up-to-date book which gives modern ideas of the universe in a way easy to follow.

HELEN SAWYER HOGG

How to Make a Telescope by Jean Texereau, translated by Allen Strickler. Pages xiii plus 191; 6½ × 10¼ in. New York and London, Interscience Publishers, Inc., 1957. Price $3.50.

This little book gives instruction to a beginner in making a complete telescope. It is well organized and logically set forth.

After describing the basic principles of telescope design and including some physical optics, Texereau arrives at the desired features for a "standard" amateur telescope: an 8-inch f/6 or f/8 Newtonian reflector with altazimuth mounting. In the chapter on making the main mirror he includes a table of the kinds and amounts of the different abrasives and polishing materials required, and in an appendix he lists a number of sources for telescope-making supplies in U.S.A. The author does not advocate buying the "kits" on the market: he feels that the quality and the choice of contents is not always the best.

Other chapters describe the making of the plane diagonal mirror, the choice of eyepieces, the mounting of the optical parts and the altazimuth mounting. In the chapter called Accessories, Mirror Coating, Adjustments, it is interesting to find along with instructions for silvering a mirror, a brief description of the technique used in aluminizing a mirror. This account is given primarily "to satisfy the amateur mirror maker's curiosity", because the equipment necessary for this process is too costly for most amateurs to acquire. A very practical section tells how to ship a mirror for aluminizing to ensure that no harm comes to the newly covered surface. Adequate packaging is often neglected by amateurs.

The final two chapters deal with the use of the telescope: with the problems of turbulence in the atmosphere and with photography with the amateur's telescope. In order to photograph stellar objects (which require time exposures) an equatorial mounting is necessary, and the important features of such a mounting are given.

Jean Texereau is President of the Committee on Instruments of the Astronomical Society of France. He was first an amateur, and later became a professional optician in the Optical Laboratory of the Paris Observatory. His book, therefore, is the result of extended experience. The material first appeared as a series of articles on telescope making in *l'Astronomie*. The translation by Allen Strickler is excellent: Strickler is himself an amateur telescope maker and by profession is a scientific instrument designer.

The Foreword to the American edition is by Albert G. Ingalls, the editor of the *Amateur Telescope Making* books. He states: "As the editor of books on the same subject as this, I am happy to move over on the

optical bench to make room for Jean Texereau and his book." This is a high recommendation for the book.

RUTH J. NORTHCOTT

The Face of the Sun by H. W. Newton. Pages 208; 4½ × 7 in. (paper). Harmondsworth, Middlesex, Penguin Books Ltd., 1958. Price, 3*s*. 6*d*.

In this book the author, a distinguished worker in the field of solar-terrestrial relationships, describes the remarkable disturbances that occur on the visible surface and in the upper atmosphere of the sun, and the effects that these disturbances have on the earth.

As an introduction to the topic of the sun's face, the first chapter reviews the present state of knowledge about the sun's interior, and the source of solar energy. Then, the photosphere, chromosphere, and corona are described.

The next five chapters are devoted to sunspots. This subject is particularly well-treated by the author. He gives a good discussion of present techniques and observations, and shows how these techniques have developed over the centuries by referring to the observations of some outstanding workers. It is most interesting to follow this development from Galileo, who recorded spots on an "unblemished" sun, to the modern spectrohelioscope.

Included also in the book are records of sunspot numbers since 1750, times at sunspot maxima and minima, and the statistics of all of the largest sunspots.

Flares and prominences are described in one chapter. Here the discussion is thorough, but not as complete as that on the sunspots.

Too often, books on solar disturbances fail to mention the effect of these disturbances on the earth. Here, however, the effects are clearly treated. Aurorae, magnetic storms, and radio blackouts all have their origin in outbreaks on the sun. Each of these phenomena is described, and an attempt is made to relate them to some aspect of the sun, such as sunspot, flare, or prominence.

The single criticism lies with the last chapter, which attempts to relate the sun to the other stars of our galaxy. Such a chapter is undoubtedly necessary, but it is difficult to write because of the complexity of the field. This, in fact, is the author's difficulty; he rambles on without actually showing the relationship.

The book, on the whole, is well written, and is both interesting and informative. This is not its only merit, however; it also encourages the reader's continued interest in a fascinating subject.

DAVID HOGG

The Individual and the Universe by A. C. B. Lovell (The BBC Reith Lectures, 1958). Pages 111; 5 × 7½ in. London, Oxford University Press, 1959. Price $2.25.

Professor Lovell is Director of the Jodrell Bank Experimental Station and the man behind Britain's huge 250-foot radio telescope. He is well known as a scientist and as the author and co-author of several text-books on radio astronomy. This book is neither a scientific research report nor a text-book, and radio astronomy is emphasized in one lecture only. Instead, it is a refreshing discussion of the significance of astronomical ideas in our time.

The first lecture is a review of the development of astronomical thought during the Middle Ages; the second deals with the current status of the theory of the origin of the solar system; the third is on the question of the interpretation of modern observations of the universe at large. The solution of the current problems, Professor Lovell warns, may lead to as complete a revision of concepts as that which earlier followed Galileo and Newton, and it may be accompanied by the same difficulties and conflicts.

The fourth lecture is devoted to the relation between astronomy and the state. This is an important new consideration in our science, which is rarely exposed to frank discussion.

The last two lectures are on the origin of the universe, because Professor Lovell believes it to be the greatest challenge to the intellect which faces man.

Radio is an excellent medium for essays of this nature, but the carefully thought-out ideas are all too often lost. It is gratifying that these stimulating lectures, which are in the tradition of Eddington and Jeans, have been published in book form.

DONALD A. MACRAE

Exploring the Distant Stars by Clyde B. Clason. Pages 384; 6 × 8½ in. New York, G. P. Putnam's Sons; Toronto, Longmans, Green and Company, 1958. Price $5.00.

The subtitle of this book: "Thrilling adventures in our Galaxy and beyond" gives a clue to the way the subject is handled: the style is colloquial. Although the style is sometimes irritating, the ideas are described in a way that can easily be understood. Some mathematics is included, but it is mostly simple arithmetic.

The title also indicates that the book is primarily about stars and not the solar system (although brief descriptions of the members of the solar

system are included). The book is divided into four parts: Mapping the Heavens, The Attack on the Stars, Stars in Action, and Exploring the Galaxies. An appendix lists the books and articles read by the author in the preparation of his book, and a page of miscellaneous astronomical data headed "Handy Facts for Star Calculators". All through the book it is evident that the author is well aware of what confuses the layman, and he has simplified these concepts.

It is inevitable that some errors or misconceptions should be included in a book by "an astronomical layman". The signs of the zodiac and the constellations of the zodiac seem to be confused. In the chapter "Seasonal Constellations" it is stated that "the star clock lags behind, and the stars rise four minutes earlier each evening"; in fact the star clock *gains* on the solar clock. On page 131 the author is perplexed by the variety of values of the "astronomical unit" quoted in the literature. The value of the astronomical unit is fixed at 92,897,416 statute miles for all astronomical computations in the nautical almanacs, regardless of the different measurements. On page 162 the name of the David Dunlap Observatory is incorrectly spelled "Dunlop"—a common error, unfortunately.

Exploring the Distant Stars makes interesting reading for those who wish to have a better understanding of what lies behind the astronomers' conclusions about the universe.

RUTH J. NORTHCOTT

BRIEF NOTICES

Stark Broadening Functions for the Hydrogen Lines by Anne B. Underhill and John H. Waddell, National Bureau of Standards Circular 603. Pages viii plus 94; 8 × 10¼ in. (paper). Washington, U.S. Government Printing Office, 1959. Price 65¢.

This is a tabulation of the intensities of the Stark components of the hydrogen lines and the Stark broadening functions $S(\alpha)$, which result from the simple adiabetic theory of the Stark effect in stellar atmospheres. The work is a result of the collaboration between the Boulder Laboratories of the U.S. National Bureau of Standards, the Sacramento Peak Observatory of the Geophysical Research Directorate of the U.S. Air Force, and our Dominion Astrophysical Observatory of the Department of Mines and Technical Surveys.

Seven-figure Trigonometrical Tables for Every Second of Time, H.M. National Almanac Office, second edition. Pages 101; 7 × 11 in. London, Her Majesty's Stationery Office, 1958. Price £1. 0*s*. 0*d*.

In astronomy it is usual to measure right ascension, hour angle and related quantities in hours, minutes and seconds of time. In orbit computation trigonometrical functions of these quantities are required. These tables have been compiled to give directly the trigonometrical functions with the argument expressed in time, to avoid the laborious conversion to degrees, minutes and seconds of arc. The first edition appeared in 1938; the present edition is a photo-lithographic reproduction of the original with the known errors corrected.

Relativity for the Layman by James A. Coleman. Pages 126; 4½ × 7 in. (paper). Harmondsworth, Middlesex, Penguin Books Ltd., 1959. Price 70¢.

The material in this paper-backed book first appeared in 1954 (see review in this JOURNAL, vol. 49, p. 135). This is a non-mathematical account of the history, theory and proofs of relativity.

NOTES FROM OBSERVATORIES

DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B.C.

Miss Anne K. Lucas joined the seismology staff on June 1. The seasonal appointments include Dr. W. H. Wehlau of the University of Western Ontario, and the following University students: R. L. Hemmings (seismology), F. C. J. T. Loehde, S. C. Morris, A. Perry-Whittingham (geomagnetism), and K. J. Rooney.

The construction of a Bowen-type all-reflecting spectrograph is nearly complete. It will provide a 4-inch beam. The equivalent focal length of the collimator is 72 inches and of the camera, 8 inches. This will give a dispersion of 40 A./mm. when used with the third order of a 10,000 lines-per-inch grating.

S. H. Draper attended the convention of the Pacific Northwest Photographers in Vancouver in February; Miss A. B. Underhill the American Astronomical Society Meetings in Rochester in March; and Miss J. K. McDonald the meetings of the Astronomical Society of the Pacific in San Francisco in June. A. McKellar gave an invited paper at the symposium on Molecular Structure and Spectroscopy at Ohio State University in June. R. M. Petrie was the guest speaker at the July convention of the Astronomical League, Northwest Region held in Tacoma, Washington.

The seismology division continued their studies of the coastal structure by means of depth charges dropped in the Straits of Georgia, with the co-operation of the Royal Canadian Navy.

During the visit of R. G. Madill of the Dominion Observatory in June, construction was begun on a permanent magnetometer building. Other visitors at the Observatory included H. L. Welsh of the University of Toronto and J. B. Irwin of the University of Indiana.

VARIABLE STAR NOTES

By Margaret W. Mayall
The American Association of Variable Star Observers, Cambridge, Mass.

The beautiful Lake Shore Front of Chicago was the site of the 1959 Spring Meeting of the A.A.V.S.O. The meeting was held there at the very kind invitation of the Chicago Astronomical Society and Dr. Albert V. Shatzel, Director of the Adler Planetarium. The Planetarium proved to be an ideal place for a summer meeting, situated, as it is, at the end of a long promontory which stretches out into Lake Michigan.

The hosts did everything possible for the pleasure and convenience of their guests, including a chartered bus for the trip through Chicago to Evanston during rush hour traffic, in order to arrive at the Georgian Hotel on time for a delicious dinner. After the dinner, Dr. Shatzel held Open House at the Dearborn Observatory and every one had a chance to see the famous 18-in. refractor and also see the great computing machine in action.

A record list of 42 applications for membership was presented to the Council, and the following were elected to Annual Membership in the A.A.V.S.O.: William K. Aiken, *South Carolina*; George C. Allan, *California*; Robert E. Allin, *Edmonton, Alta., Canada*; David V. Anderson, *Illinois*; Roy E. Anderson, *Florida*; Harry L. Bibber, *Virginia*; Curtis P. Bight, *New York*; Robert F. Brady, *Georgia*; Andrew M. Brown, *Virginia*; Clarion A. Cochran, *California*; Ronaldo Rogerio De Freitas, *Rio de Janeiro, Brazil*; Raymond R. Dudley, Jr., *California*; Clare Michael Fetrow, Jr., *Maryland*; R. C. Freeze, Jr., *Oklahoma*; Charles H. Giffen, *Wisconsin*; George Glagola, *Ohio*; John F. Gothard, *California*; Roger W. Grossenbacher, *Ohio*; Carolyn J. Hurless, *Ohio*; Roger Alan Kopp, *Michigan*; Herman W. Lang, *Missouri*; David C. R. Leckey, *Winnipeg, Man., Canada*; Nicholas Liepins, *Illinois*; Albert D. Maizels, *District of Columbia*; Moose Jaw Astronomical Society, *Moose Jaw, Sask., Canada*; Wayne Morrow, *Kentucky*; Margaret Olmsted, *Maine*; Omaha Astronomy Club, *Nebraska*; Douglas P. Reagan, *New York*; Edward G. Schmidt, *Montana*; Roger Schneier, *New York*; Jacqueline L. Schroedter, *California*; Duane D. Smith, *New York*; South Shore Astronomical Society, *Massachusetts*; Richard Stanton, *California*; James H. Templeton, *Texas*; Helen A. Underwood, *New York*; Alan Van Til, *Indiana*; Wallace W. Wallin, *Illinois*; Janice B. Waude, *Illinois*; Linda Layne Williford, *Mississippi*; and Benjamin H. Zellner, III, *Georgia*.

Ralph A. Buckstaff, President of the A.A.V.S.O., announced that the Council had voted to accept with the greatest of pleasure, an invitation from Dr. Peter M. Millman and the Ottawa Centre of the Royal Astronomical Society of Canada for the A.A.V.S.O. to hold a meeting in the Spring of 1961 in Ottawa. Everyone remembers the fine meetings we have had in Canada in the past—in Montreal in 1957, and in Toronto in 1940. The 1959 Annual Meeting will be held in Massachusetts in October at the time of the total solar eclipse, and the Spring 1960 meeting will be held in New York City.

An interesting and varied group of papers was presented at the meeting. A.A.V.S.O. Abstracts have been published which report the papers in more detail. Dr. George Van Biesbroeck opened the meeting with a fine talk about our old friend Mira (omicron Ceti). He spoke of one of the intriguing problems of Mira which has not been of much concern to variable star observers—its duplicity. Observers with large telescopes should certainly try to observe the companion whenever possible, but the two stars are coming closer together, and therefore becoming more and more difficult to separate.

Other papers included, "Bode's Law Modernized", by George Diedrich, in which he developed an easy way to remember the distances of the planets. Robert M. Adams spoke on "A Graphic Study of V Sagittae". As a result of the interest aroused in this star, the A.A.V.S.O. has initiated a programme of special observations at specified times, in order to attempt to confirm some of the peculiar variations.

A report was given of a paper by Takashi Murayama of Japan, on "Cosmic Ray Data and Variations of W Orionis". He found a marked correlation between the intensity of cosmic rays from a point in the sky near W Orionis, and the light curve of that star.

Another paper from the Orient was one by the late Dr. Chang Yuin, "Explanation of Photographic Light Curves of Very Short Period Variable Stars", in which he showed that many of the supposed characteristics of the curves of variables with periods less than half a day may be a photographic effect, caused by the length of exposure. Dr. Chang proposed a programme of photographing star trails in an attempt to discover variables with periods less than one hour. With an exposure of one hour, any variation with a period approximately equal to or less than one hour, would be almost completely "washed out". At the present time, the star with the shortest known period is CY Aquarii, period 88 minutes.

Joseph A. Anderer spoke on "Astronomical Postage Stamps" and illustrated his remarks with Kodachrome slides of many beautiful examples from all around the world. Margaret W. Mayall reported on "A New Variable Star in Camelopardalis", discovered by Robert Greenley and observed by David Rosebrugh and several other members in addition to Mr. Greenley. The paper was printed in full in the last issue of this JOURNAL (vol. 53, no. 4, p. 193).

Every observer has his own method of laying out his observing programme for the month, and it is interesting to know how fellow observers do theirs. Clinton B. Ford spoke on "Programming Monthly Estimates of Variable Stars", and exhibited the blank he has made up for his own use. It assures his coverage of all available stars each month, if the weather permits. He finds that with his 10-inch reflector his list averages about 250 different variables per month.

The Director reports increasing activity among groups of observers. The Milwaukee Astronomical Society probably holds the record for the number of years of observations. They have been active for more than 25 years. Among the newer groups the one centered in Santiago de Chile and the one in Sydney, New South Wales, Australia, should be mentioned and congratulated on their fine observations.

In 1957 Miguel Valdez organized an observing group in Santiago, and under his leadership the activity continued to grow. During the first nine months of the current fiscal year, the following observers in Chile have sent in observations: Santiago Barrera, Leopoldo Celis, Rodrigo de la Vega, Gabriel Garland, Arturo Martinez, Juan Nestler, Hernan Salce, and Miguel Valdez. Sr. Valdez has recently returned to his native Peru, where he is continuing his observing and hopes to organize more

observing activity in Lima. The Variable Star section of the Asociacion Chilena de Astronomia is now under the capable direction of Juan Nestler.

The New South Wales Branch of the British Astronomical Association has had a very fine Variable Star Section for some years. Increased activity developed in 1958, when I. P. Debono, an A.A.V.S.O. observer formerly from Cairo, Egypt, was elected new Director of the Section, succeeding Dr. Trainor. Mr. Debono has enlisted the help of a number of new observers throughout New South Wales, and is also helping to organize a Junior Group in Sydney. We have received observations from the following: I. P. Debono, John Graham, F. Lewindon, Howard C. Nightingale, R. T. Price, and F. Traynor.

For a number of years, we have not had any contact with the observers at the Urania Observatory in Budapest, Hungary, but during the last year, they have again been sending in their variable star observations. They are an active group, with many observers. Among them are the following (there are discrepancies in some of the names, and some are not complete): Bakos (Babos?), Lajos Bartha, Fejes, Fekete, Ganser, Tamas Jager, Mojsza, Molnar, Pinter, Ponory, Szanto (Szantai?), Szekely, Koppany Thaly, and Tokodi.

Soon after World War II, a group of young German amateur astronomers formed the Berliner Arbeitsgemeinschaft für Veränderliche Sterne. Their membership has changed over the years as many left Berlin to go to various universities, but new observers are always appearing. Currently some very fine work is being done by Reinhard Rudolph, Werner Braune and Wolfgang Quester.

Early in 1958 a few members of the Observing and Computing section of the Rittenhouse Astronomical Society of Philadelphia made some variable star observations. Their activity has increased and the following have sent observations: Edward Anderson, D. Claus, J. H. Conklin, T. Fause, D. M. Fletcher, David O. Halvorson (formerly observed from Minneapolis), M. Hess, Jack H. Kubanoff, G. Poyner, A. Richter, and H. Vanzant.

No list of active observing groups would be complete without mention of the well-known Observing Group of the Amateur Astronomers Association of New York, under the leadership of Edward G. Oravec, and the Black River Astronomical Society (Ohio) under George Diedrich and James Breckinridge.

A.A.V.S.O. Nova Search Report (from George Diedrich, Chairman): The following 16 observers checked their nova search areas for a total of 325 observations. The number of area-nights observed by each person in March and April, 1959 is given in that order, respectively, after each name. J. Breckinridge: 0, 1; I. P. Debono: 1, 3; F. J. DeKinder: 9, 14; D. Diedrich: 12, 17; G. Diedrich: 18, 13; K. W. Doyle: 14, 0; C. L. Drolet: 11, 6; K. Fuller: 19, 10; G. Gaherty, Jr.: 15, 6; W. L. Isherwood, Jr.: 20, 14; H. C. Nightingale: 15, 14; D. L. Sands: 7, 0; F. Traynor: 3, 19; G. Wedge: 15, 25; I. K. Williamson: 6, 3; K. Zorgo, 22, 0.

The supernova discovered on June 28, 1959 was in NGC 7331 instead of our Milky Way. We cannot reprimand any of our members for not finding it because it was of the 12th magnitude. Will you be ready when the next one appears in OUR galaxy? You will be, if you follow our motto—Keep Looking.

Observations received during May and June 1959: A total of 7,529 observations was received: 3,806 from 67 observers in May, and 3,723 from 63 observers in June.

Observer	May		June		Observer	May		June	
	Var.	Ests.	Var.	Ests.		Var.	Ests.	Var.	Ests.
Adams, R. M.	88	165	63	141	Kindt, O. H.	3	4	..	..
Allin, R.	55	168	35	112	Lacchini, G. B.	..	..	5	6
Anderson, C. E.	79	105	36	41	Lewindon, F.	..	..	2	5
Anderson, E.	8	17	8	11	Lowder, W. M.	..	..	33	33
Bakos	1	1	..	..	Martinez, A. E.	..	..	1	12
Bales, R. M.	7	7	8	18	McPherson, C. A.	..	..	10	13
Ball, A. R.	18	18	15	20	Miller, W. A.	11	22	25	29
Barrera, S.	..	..	2	40	Mojsza	6	7	..	..
Bartha, L.	6	7	..	..	Molnar	3	3	..	..
Bicknell, R. H.	10	18	16	193	Montague, A. C.	20	25	15	15
Bohannon, B.	1	1	..	..	Morgan, F. P.	17	20	9	13
Braune, W.	37	330	..	..	Muniz, L.	8	25	12	29
Breckinridge, J.	2	3	5	5	Nestler, J.	..	..	19	125
Carlisle, J. H.	2	2	2	2	Nightingale, H. C.	3	10	3	18
Carpenter, C. B.	..	..	5	5	Oravec, E. G.	163	251	152	337
Celis, L.	..	..	6	65	Parker, P. O.	74	100	56	60
Cragg, T. A.	203	209	201	208	Pearcy, R. E.	3	3	2	2
Debono, I. P.	2	2	..	..	Peltier, L. C.	25	97	21	94
de Kock, R. P.	126	566	124	450	Pinter	7	37	..	..
de la Vega, R.	..	..	21	155	Price, F. J.	11	14	..	..
Diedrich, DeL.	1	2	1	1	Price, R. T.	..	..	2	2
Diedrich, G.	2	6	6	8	Quester, W.	11	47	..	..
Dudley, R. R.	18	27	22	33	Rizzo, P. V.	21	27	8	20
Ellerbe, J. E.	1	1	..	..	Robinson, J. C.	..	..	39	63
*Engelkemeir, D.	7	28	7	12	Robinson, L. J.	1	2	1	1
Erpenstein, O. M.	8	8	..	..	Rosalsky, R.	..	..	1	2
Estremadoyro, V.A.	12	12	4	4	Rosebrugh, D. W.	11	28	9	66
Fejes	9	37	..	..	Rosenfield, C. C.	6	6	..	..
Fekete	2	2	..	..	Rosenfield, D. A.	5	6	..	..
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